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EXHIBIT A

Section 17

Measurement and Control Circuits

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Principles of Measurement Circuits*

DEFINITIONS AND PRINCIPLES OF MEASUREMENT

1. Precision is a measure of the spread of repeated determinations of a particular quantity. Precision depends on the resolution of the measurement means and variations in the measured

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value caused by instabilities in the measurement system. A measurement system may pr... precise readings, all of which are inaccurate because of an error in calibration or a defect in ... system.

2. Accuracy is a statement of the limits which bound the departure of a measured value ... the true value. Accuracy includes the imprecision of the measurement along with all the ... mulated errors in the measurement chain extending from the basic reference standards to ... measurement in question.

3. Errors may be classified into two categories, systematic and random. *Systematic errors* ... those which consistently recur when a number of measurements are taken. Systematic errors ... be caused by deterioration of the measurement system (weakened magnetic field, change in ... reference resistance value), alteration of the measured value by the addition or extraction ... energy from the element being measured, response-time effects, and attenuation or distortion ... the measurement signal. *Random errors* are accidental, tend to follow the laws of chance, and ... not exhibit a consistent magnitude or sign. Noise and environmental factors normally produ... random errors but may also contribute to systematic errors.

TABLE 17-1 Factors for Establishing Confidence Interval*

Number of observations	Confidence level 0.50	0.90	0.95	0.99
	Confidence interval			
2	$X \pm 1.00s$	$X \pm 6.31s$	$X \pm 12.71s$	$X \pm 63.66s$
3	$X \pm 0.82s$	$X \pm 2.92s$	$X \pm 4.30s$	$X \pm 9.92s$
4	$X \pm 0.77s$	$X \pm 2.35s$	$X \pm 3.18s$	$X \pm 5.84s$
5	$X \pm 0.74s$	$X \pm 2.13s$	$X \pm 2.78s$	$X \pm 4.60s$
6	$X \pm 0.73s$	$X \pm 2.02s$	$X \pm 2.57s$	$X \pm 4.03s$
7	$X \pm 0.72s$	$X \pm 1.94s$	$X \pm 2.45s$	$X \pm 3.71s$
8	$X \pm 0.71s$	$X \pm 1.90s$	$X \pm 2.37s$	$X \pm 3.50s$
9	$X \pm 0.71s$	$X \pm 1.86s$	$X \pm 2.31s$	$X \pm 3.36s$
10	$X \pm 0.70s$	$X \pm 1.83s$	$X \pm 2.26s$	$X \pm 3.25s$
11	$X \pm 0.70s$	$X \pm 1.81s$	$X \pm 2.23s$	$X \pm 3.17s$
16	$X \pm 0.69s$	$X \pm 1.75s$	$X \pm 2.13s$	$X \pm 2.95s$
∞	$X \pm 0.67s$	$X \pm 1.64s$	$X \pm 1.96s$	$X \pm 2.58s$

* Modified and abridged from Table IV of R. A. Fisher and F. Yates, "Statistical Tables for Biological, Agricultural ... Medical Research," Oliver & Boyd, Edinburgh, 1963. By permission of the authors and publishers.

The arithmetic average of a number of observations should be used to minimize the effect of random errors. The arithmetic average or mean X of a set of n readings $X_1, X_2, \ldots, X_n$ is

$$X = \Sigma X_i / n$$

The dispersion of these readings about the mean is generally described in terms of the standard deviation σ, which can be estimated for n observations by

$$s = \sqrt{\frac{\Sigma(X_i - X)^2}{n - 1}}$$

where s approaches σ as n becomes large.

A *confidence interval* can be determined within which a specified fraction of all observed values may be expected to lie. The *confidence level* is the probability of a randomly selected reading falling within this interval. Confidence intervals are given in Table 17-1 as a function of the number of observations and the required confidence level. Detailed information on measurement errors is given in Ref. 1, Par. **17-160**.

4. Standardization and calibration involve the comparison of a physical measurement with a reference standard. Calibration normally refers to the determination of the accuracy and linearity of a measuring system at a number of points, while standardization involves the adjustment of a parameter of the measurement system so that the reading at one specific value is in correspondence with a reference standard. The numerical value of any reference standard should be capable of being traced through a chain of measurements to a National Reference Standard maintained by the National Bureau of Standards.

5. The **range** of a measurement system refers to ... system is designed to provide satisfactory measu... a measurement should be chosen so that the rea... cision. An instrument having a linear scale which ... d only within 2% at half scale.

6. The **resolution** of a measuring system is define... ntity which can be distinguished. The resolution ... deflection per unit input. Instruments having a squar... full scale as linear-scale instruments. Amplification a... deflection in the region of interest and thereby inc... ately limited by the magnitude of the signal th... background.

7. **Noise** may be defined as any signal which doe... introduced in measurement systems by mechanical c... fields. The coupling of external noise can be reduced by ... and electromagnetic shielding. Electrical noise is ofte... its harmonics, as well as at radio frequencies.

In systems containing amplification, the noise introd... ... because the noise components within the amplifier ... signal. The noise in the output determines the lower li... Even if external noise is minimized by shielding, fi... duced by random disturbances within the system caus... motion in mechanical systems, Johnson noise in electr... in magnetic elements. Johnson noise is generated by el... of a circuit. The equivalent rms noise voltage develope... perature T is equal to $\sqrt{4kTR\,\Delta f}$, where k is Boltzman... the bandwidth in hertz over which the noise is observe...

8. The **bandwidth** Δf of a system is the difference ... passed by the system (see Par. **17-44**). The bandwidth ... follow variations in the quantity being measured. The lo... their response time is approximately equal to $1/(3\Delta f)$. A... response time, it makes the system more susceptible to ...

9. **Environmental factors** which influence the accu... temperature, humidity, magnetic and electrostatic influe... tion, and position. Temperature changes can alter the v... duce thermally generated emfs, cause variations in the d... alter the properties of matter. Humidity affects resistan... organic materials. DC magnetic and electrostatic fields ... which are sensitive to these fields, while ac fields can i... stability can alter instrument reference values and pr... energy imparted to the system in the form of shock or v... and if severe enough, can result in permanent damage. ... the measurements because of the influence of magnetic, ...

TRANSDUCERS, INSTRUMENTS, AND INDICATORS

10. **Transducers** are used to respond to the state of a ... this state into a convenient electrical or mechanical q... according to the variable to be measured. Variable classi... physical, chemical, nuclear-radiation, electromagnetic-r... detailed in Sec. **10**.

11. **Instruments** can be classified according to whether ... Analog instruments include the d'Arsonval (moving-coil ... ment, moving-iron instrument, electrostatic voltmeter, g... oscilloscope, and potentiometric recorders. Digital-indica... readout of the quantity being measured and have the adv... make rapid and accurate readings.

12. **Indicators** are used to communicate output infor... to the observer.